ECMWF-Interim

Eastward and Meridional (ua,va) Wind from Reanalysis

1. Intent of this document

This document is intended for users who wish to compare atmospheric reanalyses, specifically the ECMWF-Interim (or ERA-Interim), with climate model output in the context of the CMIP5/IPCC experiments. This document summarizes essential information needed for comparing eastward (ua) and meridional (va) winds to climate model output. For the most part, this information was extracted from:
http://www.ecmwf.int/publications/library/do/references/show?id=90276
and
http://onlinelibrary.wiley.com/doi/10.1002/qj.828/abstract.

Data set file name (as it appears in the ESGF)
ua_assimilation-ECMWF_level-4_v1.0_197901-197912.nc
va_assimilation-ECMWF_level-4_v1.0_197901-197912.nc
Contact
D. P. Dee email: Dick.Dee@ecmwf.int
ESGF Technical Contact:
Denis Nadeau email: denis.nadeau@nasa.gov

This contribution represents the first reanalysis-based data set introduced to obs4MIPs and the technical note structure and content requirements for reanalysis data sets are still under development as more fields and reanalysis products are being considered.

Data Field Descriptions

CF variable name, units	ua, ms^{-1} va, ms^{-1}
Spatial resolution	The vertical resolution is determined by the CMIP5 mandatory levels.[1] The longitude and latitude resolution is a T255 spherical-harmonic representation (approximately 79 km)
Temporal resolution and extent:	Monthly averages from 4-times daily values (0,6,12,18 UTC) from 1979-2013.
Coverage:	Global

[1] For the obs4MIPs project only 17 levels are used which correspond with the required levels used in the CMIP5 specifications.

3. Data Origin

The ERA-Interim atmospheric model and reanalysis system uses cycle 31r2 of ECMWF's Integrated Forecast System (IFS), which was introduced operationally in September 2006. Documentation of the IFS is published on the ECMWF website at http://www.ecmwf.int/research.

The ERA-Interim reanalysis is produced with a sequential data assimilation scheme, advancing forward in time using 12-hourly analysis cycles. In each cycle, available observations are combined with prior information from a forecast model to estimate the evolving state of the global atmosphere and its underlying surface. This involves computing a variational analysis of the basic upper-air (defined as atmospheric levels above 10m) atmospheric fields (temperature, wind, humidity, ozone) and surface pressure, followed by separate analyses of near-surface parameters (2 m temperature and 2 m humidity), soil moisture and soil temperature, snow, and ocean waves. The analyses are then used to initialize a 12 hour model forecast, which provides the prior state estimates needed for the next analysis cycle.

The data assimilation thus produces a coherent record of the global atmospheric evolution constrained by the observations available during the period of reanalysis. The ERA-Interim archive currently contains 6-hourly (0, 6, 12, 18 UTC) gridded estimates of three-dimensional (3D) meteorological variables, and 3-hourly estimates of a large number of surface parameters and other two-dimensional (2D) fields, for all dates from 1 January 1989. The complete contents of this archive are described in Berrisford *et al*. (2009).

3.1 Input datasets

Observations assimilated in ERA-Interim for all dates prior to 2002 consist mainly of input data originally prepared for ERA-40. These data and their sources are described in Uppala *et al*. (2005) and include such data as: operational Global Telecommunication System (GTS) data (surface, radiosondes, pilot, dropsonde, profiler, aircraft and cloud motion winds), NOAA TOVS/HIRS/MSU/SSU, SSM/I, radiosondes and pilot data from NCAR, COADS, NCEP operational GTS data, US Navy, Tropical Atmosphere and Ocean (TAO) buoy array, and many other sources.

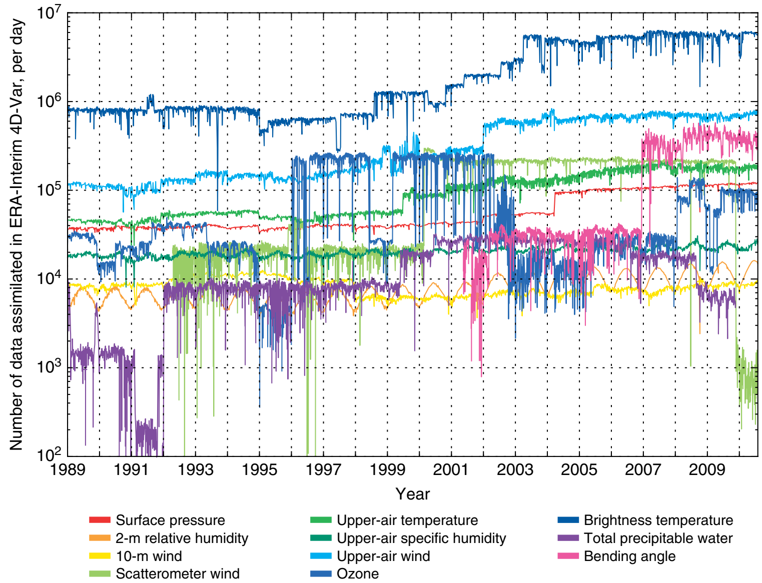

Figure 1. Daily counts, on a logarithmic scale, of observations assimilated in the atmospheric analysis component of ERA-Interim. Note: the ERA-Interim now dates back to 1979.

The number of observations assimilated in ERA-Interim has increased from approximately 10^6 per day on average in 1989, to nearly 10^7 per day in 2010. Figure 1 shows, on a logarithmic scale, the daily counts for all observations used in the atmospheric 4D-Var analysis. The overwhelming majority of data, and most of the increase over time, originate from satellites. This includes clear-sky radiance measurements (quantified as brightness temperatures) from polar-orbiting and geostationary sounders and imagers, derived from geostationary satellites, scatterometer ocean surface wind data, and ozone retrievals from various satellite-borne sensors. Also derived from satellite observations are the total precipitable vapor estimates produced within the 1D+4D-Var scheme described in section 2.1.6. Measurements of atmospheric refraction (quantified as bending angles) obtained from GPS radio occultation began to be used in ERA-Interim in 2001, growing an order of magnitude near the beginning of 2007.

The conventional observing system, in spite of much lower data volumes, still serves as an indispensable constraint to the atmospheric reanalysis. *In situ* measurements of upper-air temperatures (*T*), wind (*ua, va*), and specific humidity (*q*) were available from radiosondes, pilot balloons, aircraft, and wind profilers. Data counts for these sources are more or less steady during the reanalysis period, with the exception of aircraft reports whose numbers increased greatly after 1998 (not shown). Observations of surface pressure (*Ps*), 2m temperature, 2m relative humidity (*RH*), and near-surface (10m) winds from ships, drifting buoys, and land stations were also assimilated in steady numbers. The light blue line represents the number of observations for the ua and va wind components. A list of the observations used in the ECMWF-Interim can be found in: http://www.ecmwf.int/publications/library/ecpublications/_pdf/era/era_report_series/RS_4.pdf. As much as 95% of the data assimilated come from satellites and a plot of the history for the satellite data system is shown in Figure 2 and an example of the spatial distribution for a 6-hour period in Figure 3.

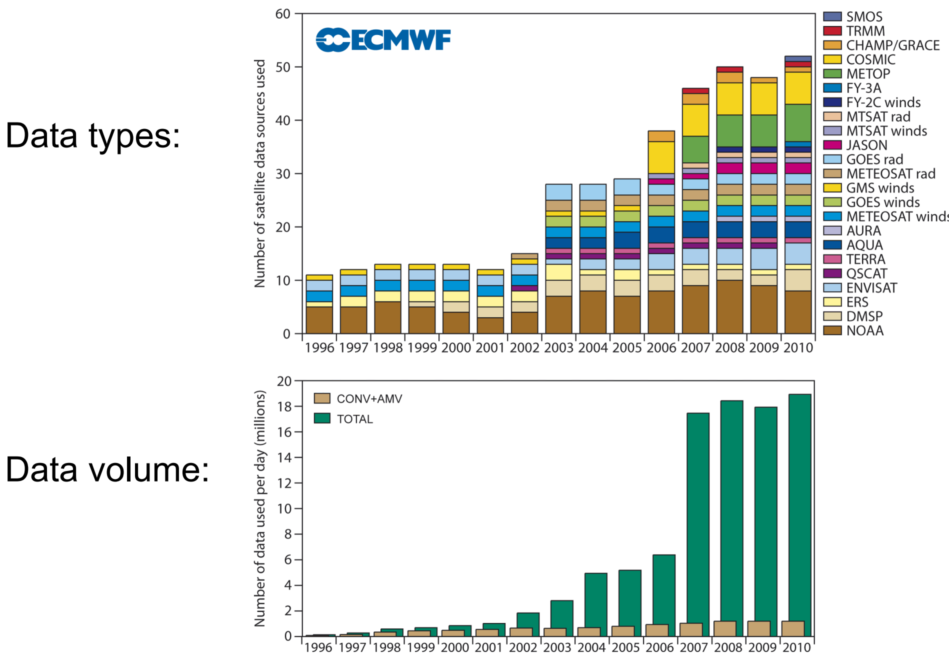

Figure 2. The growth history of the satellite observing system used in the ECMWF Interim reanalysis.

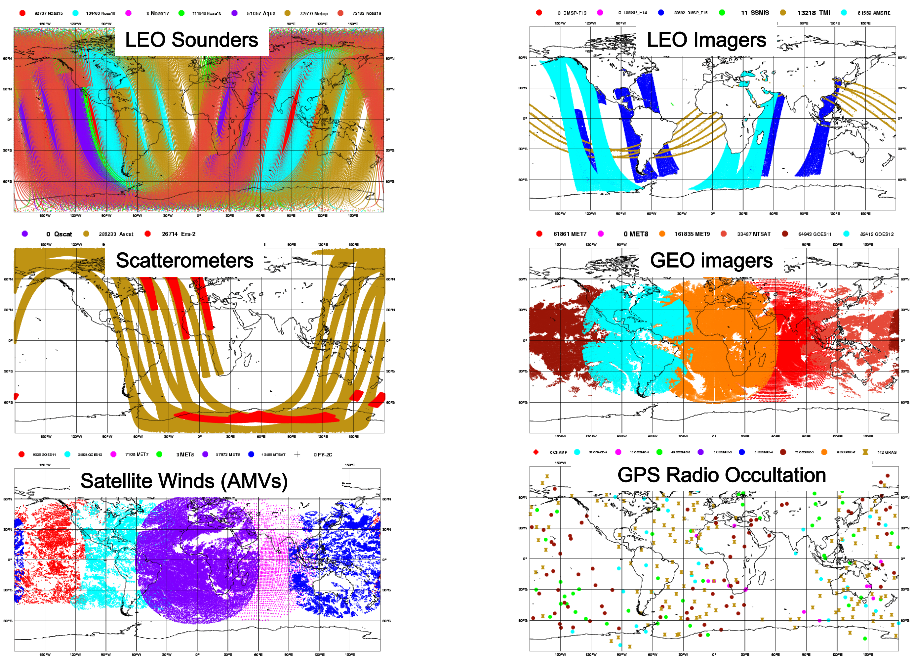

Figure 3. The spatial sampling of a typical 6-hour period. Geostationary satellites (GEO) imagers produce large regional coverage but do not provide global coverage by a single satellite. Atmospheric Motion Vectors (AMS) are taken from the GEO satellites. Global Positioning System (GPS) satellites provide wind, temperature, humidity and pressure. Low earth orbiters (LEO) imagers provide global coverage with a single satellite but have a low temporal resolution. The later are the best for numerical weather prediction.

4. Validation and Uncertainty Estimate

All observations used in ERA-Interim are subject to a suite of quality control and data selection steps. Various preliminary checks serve to detect errors that can occur when measurements are recorded or transmitted. These include checks for completeness of reports, physical feasibility, integrity of ship routes and aircraft flight tracks, hydrostatic consistency of radiosonde profiles, and the occurrence of duplicate reports. Observations that fail any of these checks are flagged for exclusion from further analysis. Quality information generated prior to and during the analysis, along with data departures, are stored with the observations and can be made available for later investigation.

Reanalyses assimilate as many observations as possible, leaving very few independent observations for validation. The innovations (observation minus the background forecast) and analysis increments (analysis minus background forecast) provide some information on the quality of the analyses, as well as on the consistency of the different observations and how they are represented in the analysis. For example, if the model forecasts, from which the background analysis is based, has a particular bias in the wind field in a particular region, there will be systematic biases between the observations and background forecast, and thus the innovations and analysis increments will exhibit these biases. While the innovation and analysis increment fields contain significant information on analysis uncertainty and error, it has yet to become readily feasible to provide these data. Rather, the broader analysis community typically relies on comparisons with other reanalyses to provide insight into uncertainties, keeping in mind that no reanalysis can be regarded as "truth", especially in regions of low observation density and for unobserved variables.

Reanalysis accuracy is difficult to summarize but there are numerous papers that address the issues for specific cases like:
http://journals.ametsoc.org/doi/abs/10.1175/2010BAMS3070.1 and
http://www.ecmwf.int/research/era/do/get/index/QualityIssues.

4.1 Analysis Increments

As described in section 3, the ERA-Interim data assimilation advances in 12-hourly analysis cycles, each of which produces an adjustment to the prognostic model variables needed to maintain consistency of the model state estimates with the available observations. The 4D-Var analysis produces a model trajectory that gives the best fit to observations in a 12-hour interval so data can be output at any desired frequency. These state adjustments, which are usually referred to as analysis increments, represent the net response of the variational data assimilation to all observations used. They therefore provide sensitive diagnostics of the end-to-end performance of the system. Although the variability of the analysis increments depends on the amount of information extracted from the input observations, the relationship is not straightforward. For example, small increments can be the sign of a very good forecast model, but they can also be due simply to a lack of observations. In a sparsely observed situation, increased variability can be expected with increased data coverage, but may also indicate improper use of certain types of observations. Mid- and upper- tropospheric wind information greatly increased in 2002 (see Fig. 1), most likely due to the introduction of clear-sky radiance observations from GOES-8 and GOES-10.

5. Consideration for Model-Reanalysis Comparisons

Obs4MIPs is utilizing reanalysis for specific quantities because they are anchored through the data assimilation framework by real observations, and lacking other direct, uniform global measurements, considered to be the best "observations" available. Zonal and meridional wind (ua, va) represent two variables in this category; such fields are distinguished from fields like precipitation that do not have direct observation counterparts assimilated but rather are strongly determined by the model equations.

The strengths and limitation of various reanalysis products is nicely summarized in:

https://climatedataguide.ucar.edu/climate-data/atmospheric-reanalysis-overview-comparison-tables and for ECMWF: https://climatedataguide.ucar.edu/climate-data/era-interim.

5.1 Impact of Observing System Changes

Observing system changes often manifest themselves in reanalysis time series by abrupt variations or discontinuities. These impacts from observing system changes, which tend to be amplified by model biases, must be distinguished from real climate variations and pose perhaps the greatest challenge for the next generation of reanalyses.

It is not recommended to use reanalysis for trend analysis because of changes in the observing system and because occasionally when two data streams merge, a trend appears that is an artifact of the merge.

5.2 Other sources

See https://climatedataguide.ucar.edu/reanalysis/atmospheric-reanalysis-overview-comparison-tables and http://reanalysis.org/ for more information on using reanalysis data sets.

6. References

Berrisford P, Dee DP, Fielding K, Fuentes M, Kållberg P, Kobayashi S, Uppala SM. 2009. *'The ERA-Interim Archive'*. *ERA Report Series*, No. 1. ECMWF: Reading, UK.

Uppala SM, Kållberg PW, Simmons AJ, Andrae U, Da Costa Bechtold V, Fiorino M, Gibson JK, Haseler J, Hernandez A, Kelly GA, Li X, Onogi K, Saarinen S, Sokka N, Allan RP, Andersson E, Arpe K, Balmaseda MA, Beljaars ACM, Van De Berg L, Bidlot J, Bormann N, Caires S, Chevallier F, Dethof A, Dragosavac M, Fisher M, Fuentes M, Hagemann S, Hólm E, Hoskins BJ, Isaksen L, Janssen PAEM, Jenne R, McNally AP, Mahfouf JF, Morcrette J-J, Rayner NA, Saunders RW, Simon P, Sterl A, Trenberth KE, Untch A, Vasiljevic D, Viterbo P, Woollen J. 2005. The ERA-40 re-analysis. *Q. J. R. Meteorol. Soc.* **131**: 2961 – 3012.

7. Datasest and Document Revision History

Rev 0 – 28 Oct 2013 – This is a new document/dataset.